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RELATIONSHIPS BETWEEN ANTHROPOMETRIC AND BODY COMPOSITION MEASURES TO ARMY PHYSICAL FITNESS TEST PERFORMANCE AMONG MALE AND FEMALE ROTC CADETS

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SUMMARY

The purpose of this study was to determine the relationships between body composition measures and Army Physical Fitness Test (APFT) performance between male and female Reserve Officers' Training Corps (ROTC) cadets prior to enlistment. Retrospective APFT test performance and body composition data were provided for 57 male and 17 female university ROTC cadets. Descriptive statistics were derived for all variables and separated by sex. A MANOVA model was used to determine differences between sexes in all anthropometric and fitness variables. A Pearson's moment correlation was used to determine significant relationships between body composition and APFT measures separated by sex. Significant differences between male and female cadets for height, body mass, body fat percentage, and APFT events were found ($p = 0.001$-0.03). No significant differences were found between sexes for BMI ($p = 0.887$). Additionally, no significant relationships between anthropometric measures and fitness performance were observed among male or female cadets.

Ključne reči: military; soldiers; push-ups; sit-ups; aerobic fitness

INTRODUCTION

Army Reserve Officers' Training Corps (ROTC) is a college program designed to educate, train, and prepare college students to become officers within the United States Army (Mele, 2020). Physical fitness is emphasized within these programs to prepare cadets for the physical demands of essential job tasks they will encounter once they commission into active duty. Some of the most common demands include weight loaded marching, running, overcoming obstacles, crawling, jumping, and hand-to-hand combat (Oliver et al., 2017). For these reasons, cadets are required to meet a minimum physical fitness standard prior to graduating and becoming commissioned soldiers to ensure they can withstand the rigors of training, and to ensure they are able to complete Army-specific tasks.

The Army Physical Fitness Test (APFT) was the standard fitness evaluation used by the U.S. Army since 1985 to determine physical readiness and health of both active-duty soldiers and cadets (Army, 2012; Leiting, 2014). The APFT included three assessments: the 2-minute timed push-up and sit-up tests to assess muscular endurance, and a 2-mile run for time to assess aerobic fitness. While the APFT is no longer widely utilized, having been replaced by the Army Combat Fitness Test (Army, 2019), the measures included in the APFT can still be used to determine information relating to the general health and fitness of cadets and soldiers (i.e., muscular endurance and aerobic fitness) (Steed et al., 2016).

Body composition can have a significant impact on a soldier's occupational and physical performance (Crawford et al., 2011; Crombie et al., 2012). It has been suggested that an individual's body fat percentage (BF%) may be important in determining muscular endurance and aerobic performance among ROTC cadets (Crawford et al., 2011; Steed et al., 2016). This importance is highlighted by research showing that 34% of males and 38% of females in the military are considered overweight or obese (Crombie et al., 2012). Additionally, attaining and maintaining a certain level of fat-free mass may also be necessary for injury mitigation purposes among soldiers (Friedl, 2012). In a study by Crawford et al., soldiers that had higher BF% performed significantly worse on selected fitness tests than those with lower BF% and similar fat-free mass (Crawford et al., 2011). These findings suggest that higher fat mass may not only negatively impact an ROTC cadet's fitness performance, but also their general health and well-being. Therefore, achieving healthy body composition levels prior to commissioning into an active-duty role should receive dedicated attention within cadet populations.

Previous research has indicated that there are differences in the levels of physical fitness between male and female cadets and enlisted soldiers in measures of muscular endurance and aerobic fitness (B. M. Roberts et al., 2023; Steed et al., 2016). These differences may be related to a number of factors, including the propensity for males, in general, to possess greater physical stature, larger lungs, and more muscle mass compared to females (D. Roberts et al., 2016; Yanovich et al., 2008). Additionally, females, in general, tend to carry a larger amount of relative fat mass compared to males, which may increase the physiological burden of performing certain soldiering tasks (Sudom & Hachey, 2011). However, the relationships between fitness and body composition have not been thoroughly explored in the

context of ROTC cadets prior to enlistment. A greater understanding of these relationships may help inform decisions related to strength and conditioning considerations within this population.

The purpose of this study was to investigate relationships between select body composition measures and measures of muscular endurance and aerobic fitness among male and female ROTC cadets. It was hypothesized that body composition would be significantly related to all measures of physical fitness for both sexes. These findings may be used to help direct physical training programs aimed at improving overall health and fitness within these populations.

METHODS AND MATERIALS

To examine the relationship between select anthropometric measures and APFT performance, previously collected data was voluntarily provided by the university's ROTC cadre. Sex related differences in body composition and fitness performance were also assessed.

Subjects

Retrospective data were provided for 74 Army ROTC cadets from a Midwestern university, including 57 males (height: 180.36 ± 7.29 centimeters [cm]; body mass: 76.81 ± 9.81 kilograms [kg]; BMI: 23.53 ± 2.43 m/kg2) and 17 females (height: 164.81 ± 4.73 cm; body mass: 66.56 ± 13.77 kg; BMI: 23.00 ± 2.23 m/kg2). Age data was not included in the data set provided to the researchers, and therefore was not included in analysis (Farina et al., 2022). This data was collected as part of the ROTC program's yearly fitness assessment via the APFT. All research was conducted with approval from the university's institutional review board (IRB # ED-19-146-STW), and informed consent was obtained from each participant prior to data collection (Navalta et al., 2019). The study followed the recommendations of the Declaration of Helsinki ("World Medical Association Declaration of Helsinki. Ethical Principles for Medical Research Involving Human Subjects.," 2001).

Protocols

Data were collected by a senior ROTC cadre in support to a Midwestern university's program using procedures outlined by the U.S. Army for conducting the APFT (Army, 2012). Data collection for the APFT events took place at an outdoor football training facility on university grounds. For all measurements, cadets were instructed to wear standard issue PT gear for the U.S. Army (t-shirt, shorts, athletic shoes). Cadre collected anthropometric measurements for cadets prior to any physical fitness assessments. The APFT was performed in the following order for all cadets.

All cadets followed standard U.S. Army protocol for the 2-minute maximal push-up assessment (Army, 2012). Cadets were instructed to begin in the front-leaning rest position with feet no more than 30 cm apart for the duration of the assessment. On the verbal command of "Go" from their cadre, cadets would lower their body by flexing their elbows

while maintaining a consistent line from their shoulders to feet. Repetitions were considered successful if cadets were able to lower their upper arms to be parallel with the ground, and return to the front-leaning rest position (Army, 2012). The only acceptable rest position for cadets within the 120 seconds was with their arms fully extended in the front-leaning rest. If a cadet's technique deviated from these guidelines, repetitions were not counted towards their total. The assessment was terminated when the time limit was complete, the cadets reached volitional fatigue, or proper technique was unable to be maintained. The absolute number of successful repetitions were included in data analysis.

The 2-minute maximal sit-up assessment was graded by cadre according to U.S. Army standards (Army, 2012). Cadets were instructed to complete as many repetitions as possible in 120 seconds while keeping proper form, described as maintaining a 90-degree angle at the knees with feet no more than 30-cm apart flat on the ground, with fingers interlocked on the back of the head for the duration of the assessment. Another cadet was permitted to stabilize the testing cadet's ankles using their hands if requested, but no other bracing techniques were allowed. Repetitions were considered successful if a cadet was able to bring their torso to or beyond vertical (defined by the base of the neck above the base of the spine), and return to the start position (Army, 2012). This upper position was the only authorized rest position for cadets for the duration of the assessment. Repetitions were not counted towards the total if the cadet did not maintain proper form at any point. This assessment was terminated when the cadet reached volitional fatigue, when proper technique was not able to be maintained for three consecutive repetitions, or the time had elapsed. The total number of successful sit-up repetitions were included in data analysis.

The 2-mile run test was conducted outdoors on a predetermined course on university grounds. The course was not to exceed a 3% grade as outlined by APFT protocol (Army, 2012). Cadets would begin the assessment on the command of "Go" from their cadre, at which time the stopwatches would begin, and would attempt to complete the course as fast as possible. Cadre would record the completion time of each cadet to the closest second.

Anthropometric measurements (height, body mass, BMI and BF%) were measured and collected by a senior ROTC cadre one week after performing the APFT using an InBody 270 (Biospace, California, USA) device and portable stadiometer. Although this device measures a number of other body composition variables, the researchers were only provided information for BMI and BF%. For their height measurement, cadets were instructed to stand barefoot with their heels touching the back of the stadiometer, and cadre recorded the result to the closest half-centimeter. For body composition measurements, cadets were instructed to remove their shoes and socks prior to standing on the InBody 270.

Statistical Analysis

All analyses were performed using IBM statistical package for the social sciences (SPSS) (Version 24.0; IBM Corporation, New York, USA). Descriptive statistics (i.e., mean, standard deviation, minimum and maximum scores) were derived for all variables and separated by sex. A MANOVA model was used to determine differences between sexes in all anthropometric and

fitness variables. Means and standard deviations were derived for all variables included in analysis. In addition, a Pearson's moment correlation was performed to determine the relationships between body composition and measures of muscular endurance and aerobic fitness and was separated by sex among ROTC cadets. The level of significance was set at $p < 0.05$ for all the statistical analyses. The correlation coefficient strength described as per Hopkins included an 'r' value that ranged from weak (≤ 0.39), moderate (0.40–0.69) or strong (≥ 0.70) relationships (Mukaka, 2012). Partial eta squared was utilized as a measure of effect size, and included an 'η2' value that ranged from small (≤ 0.05), medium (0.06-0.14), or large (≥ 0.15) (Stevens, 2012).

RESULTS

Descriptive statistics and MANOVA results for anthropometric measurements and fitness performance results for all male and female cadets are presented in Table 1. There were significant differences between male and female cadets for height, body mass, BF%, push-ups, sit-ups, and 2-mile run. On average, males were taller, heavier, and performed better on the fitness tests than female cadets. No statistically significant differences were found between sexes for BMI.

Table 1. Descriptive statistics and MANOVA results by sex in ROTC cadets

Measure	Male ROTC Cadets		Measure	Male ROTC Cadets
HT (cm)	180.36 ± 7.29	164.34 ± 4.95 **	0.467	0.001
BM (kg)	76.81 ± 9.84	63.49 ± 6.94 **	0.248	0.001
BF% (%)	18.43 ± 6.52	25.59 ± 6.50 **	0.164	0.001
BMI (m/kg2)	23.53 ± 2.42	23.43 ± 2.10	0.000	0.887
Push-ups (reps)	57.89 ± 15.01	35.50 ± 13.98 *	0.271	0.001
Sit-ups(reps)	59.72 ± 14.49	50.07 ± 17.89 *	0.062	0.037
2-mile run (seconds)	969.07 ± 142.65	1187.93 ± 124.09 **	0.289	0.000

**= p ≤ 0.05, **= p ≤ 0.01*

The relationships between the measured anthropometric variables and fitness assessments for male ROTC cadets are displayed in Table 2. The results revealed no significant relationships between any anthropometric measures and fitness performance among male cadets.

Table 2. Correlations between anthropometric variables and fitness assessments in male ROTC cadets.

Variable		HT	BM	BF%	BMI
Push-ups (reps)	r	-0.195	-0.153	-0.081	-0.027
	p	0.147	0.257	0.551	0.842
Sit-ups (reps)	r	-0.141	-0.148	-0.162	-0.047
	p	0.294	0.271	0.228	0.731
2-mile run (sec.)	r	0.179	0.232	0.139	0.137
	p	0.184	0.082	0.304	0.309

The correlations between the measured anthropometric variables and fitness assessments for female ROTC cadets is shown in Table 3. Similar to the male cadets, no significant relationships were discovered between anthropometrics and fitness performance.

Table 3. Correlations between anthropometric variables and fitness assessments in female ROTC cadets.

Variable		HT	BM	BF%	BMI
Push-ups (reps)	r	-0.210	-0.283	0.053	-0.219
	p	0.418	0.271	0.840	0.399
Sit-ups (reps)	r	-0.183	-0.213	0.116	-0.158
	p	0.482	0.412	0.659	0.546
2-mile run (sec.)	r	-0.235	-0.091	0.062	0.275
	p	0.418	0.756	0.833	0.342

DISCUSSION

The purpose of this study was to determine if significant relationships existed between body composition and general fitness as measured by the APFT among male and female ROTC cadets. While significant differences in performance were observed between sexes, no significant relationships were found between anthropometric measurements and physical fitness performance for male or female cadets. These findings support those of previous research, in which BF% and BMI were not significantly correlated to APFT performance (Pierce et al., 2017; B. M. Roberts et al., 2023).

Sex-based differences in performance among ROTC cadets have been observed in several investigations with male cadets, in general, tending to achieve higher raw test scores when compared to female cadets (B. M. Roberts et al., 2023; D. Roberts et al., 2016). Similarly, significant differences in fitness test performance by sex were observed in this investigation, favoring male cadets on all measures, although the standard deviations suggest that fitter female cadets would outperform less fit male cadets. While previous research agrees with the findings of this research (Steed et al., 2016), whereby male ROTC cadets typically performed better in both the push-up and 2-mile run assessments when compared to female cadets, they do differ in regards to sit-up performance. There were no significant between-sex differences found in sit-up repetitions. This lack of a significant finding for the sit-ups has been found in tactical populations (B. M. Roberts et al., 2023; Yanovich et al., 2008) with research suggesting little difference between males and females in trunk endurance (Dawes et al., 2017).

Male cadets were, on average, taller, heavier, and had lower BF% in this study compared to their female counterparts. Furthermore, female cadets tended to have lower absolute upper body muscular endurance compared to males, which may partially explain the lower scores observed among females in push-up performance (Dada et al., 2017; B. M. Roberts et al., 2023). As such, females considering military service as a career path should physically prepare prior to enlistment or joining an ROTC program to reduce any sex-related differences. Additionally, ROTC programs should consider implementing ability-based training programs to capture and improve the fitness of all cadets, rather than using a “one-size fits-all” technique (Orr et al., 2016).

Previous research has reported significant positive relationships between BF% and 2-mile run time (i.e., lower BF% relating to faster run times), and significant negative correlations between BF% and push-up repetitions performed (i.e., lower BF% relating to more push-up repetitions) (Steed et al., 2016). However, as previously mentioned, no significant relationships between BF% and performance were observed in this cohort. It should be noted however, that 27% of cadets in this study were categorized as overweight or obese based on their BF% (Weir & Jan, 2019), and 23% of the cadets in this study were categorized as overweight or obese when using BMI measures. These findings are concerning, as greater BF% and BMI have been linked to an increased risk of injury within military populations (Anderson et al., 2015). Indeed, it is important that ROTC cadets as well as active-duty soldiers strive to attain and maintain healthy levels of body composition prior to commissioning to increase their overall health, well-being, and extend their occupational lifespan.

While the results of this study provide valuable insights into the impact of body composition on the physical fitness and general health of ROTC cadets, several limitations should be noted. First, this investigation was limited to one University located in the Midwest U.S. Compared to other regions; there is a higher indication of physical inactivity in the Midwest (Centers for Disease Control and Prevention, 2020). As such, research among similar populations from different geographic regions would be useful in determining the generalizability of these results. Second, while significant differences in performance were not observed based on body composition, it is unknown if cadets with greater BF% experienced greater levels of musculoskeletal and cardiovascular strain to complete these tasks in relation to their leaner counterparts. Since excess body fat creates extra physiological burden (Crawford et al., 2011), it stands to reason that cadets with greater relative amounts of non-functional mass may be required to work harder to compete the same task and potentially be at an increased risk of injury (Scott et al., 2015). Finally, in comparison to the male cadets in this study, there was a relatively low sample of female cadets. While this is reflective of the norm within the U.S. military population (Pierce et al., 2017), a larger sample of female cadets may further strengthen the relationships discovered in this investigation.

CONCLUSIONS

The purpose of this research was to investigate relationships between select body composition measures and measures of muscular endurance and aerobic fitness among male and female ROTC cadets as measured by the APFT. While significant differences in performance were observed between sexes, no significant relationships were found between anthropometric measurements and physical fitness performance for male or female cadets. ROTC programs should consider implementing ability-based training programs to capture and improve the fitness of all cadets, rather than using a “one-size fits-all” technique. It is important that ROTC cadets as well as active-duty soldiers strive to attain and maintain healthy levels of body composition prior to commissioning to increase their overall health, well-being, and extend their occupational lifespan.

PRACTICAL APPLICATIONS

Although the findings in this study do not indicate a significant relationship between body composition and fitness performance in the push-up, sit-up and 2-mile run (Steed et al., 2016; Thomas et al., n.d.), poor body composition and low levels of physical fitness could still have negative effects on long-term health and injury status. Therefore, it is important that ROTC cadets, as well as the general population that intends to enlist into service, strive to attain and maintain healthy levels of body composition prior to commissioning to increase their overall health, well-being, and extend their occupational lifespan. The significant differences in fitness between male and female cadets supports the use of ability-based training in pre-enlistment programs to account for these sex-related differences and minimize injury risk. Additionally, females considering military service as a career path should physically prepare prior to enlistment or joining an ROTC program to reduce any sex-related differences.

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